Water Quality Summary for Kenduskeag Stream and Upper Watershed Tributaries

By Mark Whiting, Maine Department of Environmental Protection

In Collaboration with Ed Lindsey
Old Town High School
(formerly of Central High School)

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Introduction:

General Watershed Characteristics:

Kenduskeag Stream is the largest tributary to the Penobscot River located below the first dam at Veazie. For this reason, Kenduskeag Stream has been of interest in Maine's salmon recovery program. The Penobscot River is the largest salmon river in Maine and it has most of the remaining Atlantic salmon (ASC 2004). However a string of dams restricts fish access to the upper river. Salmon have been maintained by fish ladders, natural reproduction in the mainstem and lower tributaries, and fish stocking by Penobscot-specific strains of salmon. Fortunately, an agreement with the dam owners, federal and state agencies, the Penobscot Indian Nation, and other private organizations will provide for the removal of the two lower dams (Veazie and Great Works), a natural looking bypass channel at another dam (Howland), and improved fish passage at four additional dams. This will improve access to over 500 river miles of fish habitat. For details on the Penobscot River recovery plan see the Penobscot River Restoration Trust website (http://penobscotriver.org/index.html).

Kenduskeag Stream is 36 miles long and has a watershed of 215 square miles. The mainstem has 12 named tributaries with subwatersheds that range in size from 3-26 square miles. French Stream, Black Stream and Crooked Brook are the largest tributaries with 26.3, 26.0 and 19.2 square miles respectively (Penobscot County Soil and Water Conservation District watershed plan, 1988). The elevation ranges from 10 feet at the confluence with the Penobscot River in Bangor to more than 1,000 feet at Preble Hill in Garland.

Garland Pond is the headwater for Kenduskeag Stream. A small dam controls the outlet stream, but the Kenduskeag is otherwise free flowing. By local standards the watershed is heavily agricultural. Approximately 40% of the active agricultural land in the Penobscot watershed is found around this lower Penobscot tributary. According to the Penobscot County SWCD watershed plan (1988) 87% of the watershed (120,000 acres) is forested primarily with mixed hardwoods, and 16,500 acres is cropland, pasture or grassland. The principal crops are corn and potatoes, with some active dairy and cattle farms. The SWCD and the Natural Resources Conservation Service have made significant progress in mitigating agricultural impacts on water quality. In the 10 years prior to the watershed plan, SWCD and NRCS have spent over $4,000,000 (including cost-shares from farmers) on water quality related improvements.

As the river enters the Bangor city limits, the nature of the river changes. The low gradient of the upper river becomes steeper, the river gives way to a series of cascades, and the river becomes confined in a rocky gorge. While the river banks are protected by a series of city parks, the original rural landscape gives way to an urban setting. The greater Bangor area has a population of about 80,000 people. An additional 23,000 live in the upper Kenduskeag Stream watershed. Bangor International Airport and the Maine Air National Guard share the large airport facility located in a tributary drainage (Birch

Stream). Maine DEP has a Total Maximum Daily Load (TMDL) pollution report for Birch Stream (DEP 2005).

Project History:

In the fall of 2003, Ed Lindsey, a teacher at Central High School in Corinth wanted to have his chemistry class engaged in a community-oriented environmental project with real life science problems. Kenduskeag Stream and four tributaries are located close to the school. The mainstem, Crooked Brook, Allen Stream, French Stream and Pierre Paul Brook became extensions of the class room.

The What Kids Can Do Foundation provided a grant for innovative teaching and improving classroom technology. Maine DEP provided some equipment and training as part of the Stream Team Program. In the spring of 2004 the class got an additional grant from the West Enfield Fund (WEF) that was established for salmon mitigation projects due to the FERC relicensing of the West Enfield Dam. The WEF money was used primarily for water chemistry analysis at the Sawyer Environmental Lab at the University of Maine. Professor Stephen Norton offered technical help and the Sawyer Lab offered a reduced rate for their laboratory services. The Penobscot Indian Nation, US Department of Commerce National Fishery Service and the Maine Department of Inland Fisheries and Wildlife helped plan the project and lent equipment and GIS assistance. In the fall of 2004, the class got an additional grant from the National Fisheries and Wildlife Foundation (NFWF) Maine Atlantic Salmon Conservation Fund for additional lab work, a laptop computer, and summer salary.

An interim report was published in 2005 (DEP 2005). This report found some turbidity problems, some high bacteria counts, and some nutrient enrichment (especially nitrate). But overall the water quality was good, five-day biological oxygen demand (BOD) was normal for an unpolluted river, and insect assemblages were indicative of a healthy system. Chlorophyll levels were indicative of a moderate trophic state.

This paper is the completion report for this project. This report will not report on BOD, chlorophyll or insect collections already mentioned in the interim report. Copies of this or the interim report are available from Mark Whiting DEP, Bangor Regional Office. John Bapst High School in Bangor will extend the available data set with field and lab analysis of the lower river in 2006. DEP will provide an analysis of this data when it is completed.

Methods:

The Central High School Stream Team, their teacher, and DEP staff took field data and collected bottles for lab analysis at five sites on six dates in 2004 and 2005. In addition to the regular sites and sample dates, some headwater and lower river sites were sampled (Table 1), and some high flow samples were collected on other dates to provide a more complete analysis of the river. The regular sample sites were just above the confluence of the tributary with the mainstem, thereby isolating the influence of each subwatershed.

Kenduskeag Stream, Crooked Brook, Allen Stream and French Stream are third order streams at our access points. Although Kenduskeag Stream is considered to be the mainstem, these four branches are approximately the same size at our sample points (25-34 feet wide). Pierre Paul Brook is a second order stream and is noticeably smaller (18 feet wide). Maps of the sample sites are provided in Appendix A.

Table 1. Regular and occasional sample sites with location information.

Site Name Regular Sites	Narrative Location	UTM Northing	UTM Easting
Crooked Brook	Above Rt 11 in Corinth	19 T 0495867	4982472
Kenduskeag Stream	Above Rt 11 in Corinth	19 T 0494253	4982216
Allen Stream	Above Rt 11 in Exeter	19 T 0493080	4981395
French Stream	Above Exeter Mills Rd in Exeter	19 T 0493583	4979641
Pierre Paul Brook	Above West Corinth Rd in Corinth	19 T 0498315	4979767
Occasional Sites			
Burnham Brook	Above the Garland Rd at a camp lot	19 T 0489442	4989730
Kenduskeag Village	Below the village bridge	19 T 0505376	4973992
Bangor	Old mill site at Lover's Leap, Valley Dr	19 T 0517219	4962198

Field measurements and equipment are provided in Table 2. All field measurements followed the Water Quality Monitoring Protocol Manual for Maine Salmon Rivers by Project SHARE (SHARE website). Once the stream staff gauges were installed in the fall of 2004, stream stage was also recorded. One flow measurement was taken using an apple and stop watch method in August of 2004. Thirteen flow measurements were taken in different flow conditions, at least once per stream in 2005. A Global Flow digital meter was used for these measurements.

Table 2. Field measurements and equipment used.

Measurement	Equipment
pH	Oakton pH Tester II
Water Temperature	Vee Gee stick thermometer
Dissolved Oxygen	YSI DO meter & LaMotte Winkler titration kit
Water Color	Hach color wheel
Turbidity	120 cm turbidity tube

Lab analysis at the Sawyer Environmental Chemistry Lab included pH, alkalinity (measured as Acid Neutralizing Capacity or ANC), major cations (calcium, sodium, potassium, and magnesium) major anions (chloride and sulfate), nutrients (nitrate and total phosphorus), dissolved organic carbon (DOC), total aluminum, total suspended solids, and turbidity. As mentioned in the Project History section, bacteria data, BOD’s, insect collections and chlorophyll data were collected in 2004 and were reported in the interim report.

Results and Discussion:

A. Weather and Hydrology:

Kenduskeag Stream does not have an active stream gauge, so weather patterns during the field seasons and relative flow are reconstructed from the Sebasticook River gauge in Pittsfield (see USGS website). Figures 1-2 provide the 2004 and 2005 gauge data for the Sebasticook, respectively.

Figure 1. Daily stream flows for the Sebasticook R for 2004.

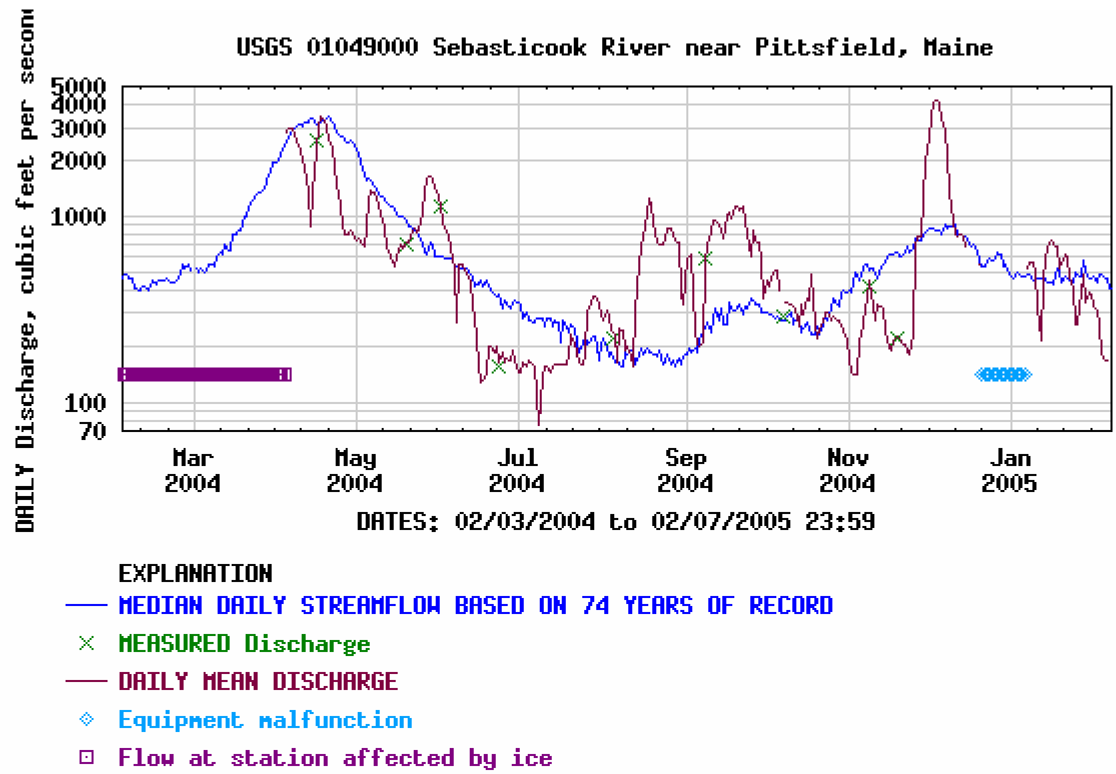
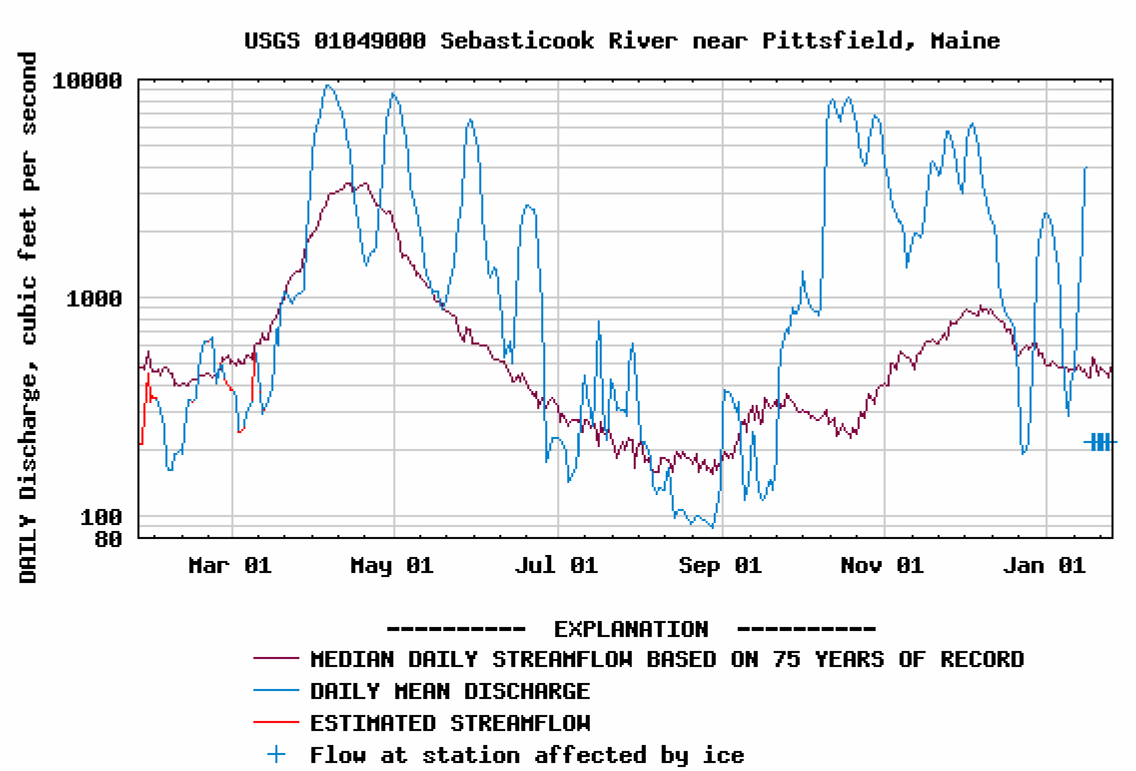


Figure 2. Daily stream flows for the Sebasticook R for 2005.



Based on the Sebasticook River gauge, the spring and early summer of 2004 were dry relative to the 74-year average. August through October were relatively wet. The remnants on Hurricane Bonnie crossed Maine on August 13. Other unnamed tropical storms followed into the fall. In 2005, except for late winter and August, the entire year was much wetter than average. April through June and October through December were especially wet. Overall, 2005 was the wettest year on record (NOAA website).

Measured flows in the Kenduskeag and tributary sites are provided in Table 3. Data from 2004 is from an apple and stopwatch method. Data from 2005 is from a digital flow meter. Note that the different streams do not react the same way to given storms or baseflow conditions. Sometimes Kenduskeag Stream has the most discharge, but sometimes Crooked, Allen or French Streams have more water. Among other things, this has to do with how rainfall is distributed in the different subwatersheds.

Table 3. Measured discharge in cubic feet per second for all sites.

Site Name	Dates	Stage in ft	Discharge cfs
Crooked Brook	8/25/2004		14.3
Kenduskeag Stream	8/25/2004		16.3

Allen Stream	8/25/2004		22.0
French Stream	8/25/2004		30.6
Pierre Paul Brook	8/25/2004		10.3
Crooked Brook	4/21/2005	1.90	108.0
Kenduskeag Stream	4/21/2005	2.30	125.0
Crooked Brook	5/25/2005	1.45	84.7
Kenduskeag Stream	5/25/2005	1.88	78.7
Pierre Paul Brook	5/25/2005	1.72	29.4
Crooked Brook	7/26/2005	0.50	3.5
Kenduskeag Stream	7/26/2005	0.88	10.4
Allen Stream	7/26/2005	1.11	2.8
French Stream	7/26/2005	1.17	4.4
Pierre Paul Brook	7/26/2005	1.00	1.6
Crooked Brook	8/20/2005	0.25	2.7
Kenduskeag Stream	8/20/2005	1.60	1.6
French Stream	8/20/2005	1.50	1.5

Because flow is needed to interpret water chemistry data, and because measured discharge is available only for certain site and date combinations, we used all available flow indicators. In addition to river stage and measured flows, we also used "relative flows" taken for a given sample date off the Sebasticook River gauge. Flows for a given year were divided by the yearly maximum and then multiplied by ten. The result is a relative flow that varies from 0-10 and has no units.

B. General Water Chemistry:

pH and Alkalinity:

The acid-base balance of water is measured as pH, which varies from 0-14. A pH of 7.0 is neutral, values from 0-6.9 are acidic, and values from 7.1-14 are alkaline. Kenduskeag Stream and the upper tributaries are slightly alkaline (Table 4). The range is about 1.0 pH unit. In contrast, the downeast salmon rivers (Narraguagus, Pleasant, Machias, E Machias, and Dennys Rivers) have a pH range that is about 3.0 pH units. This is due to their low buffering capacity and vulnerability to acid rain events (DEP 2006). Pierre Paul Brook has the lowest pH. Either Allen or French Streams have the highest pH on a given day.

Table 4. Mean pH for Kenduskeag Stream and upper tributary sites, with standard deviation and ranges.

	pH mean	No. cases	Std Dev	Range
Crooked Brook	7.69	13	0.37	7.03-8.20
Kenduskeag Stream	7.74	12	0.24	7.34-7.99
Allen Stream	7.82	13	0.29	7.23-8.09
French Stream	7.81	13	0.29	7.28-8.14
Pierre Paul Brook	7.59	13	0.38	7.01-8.05

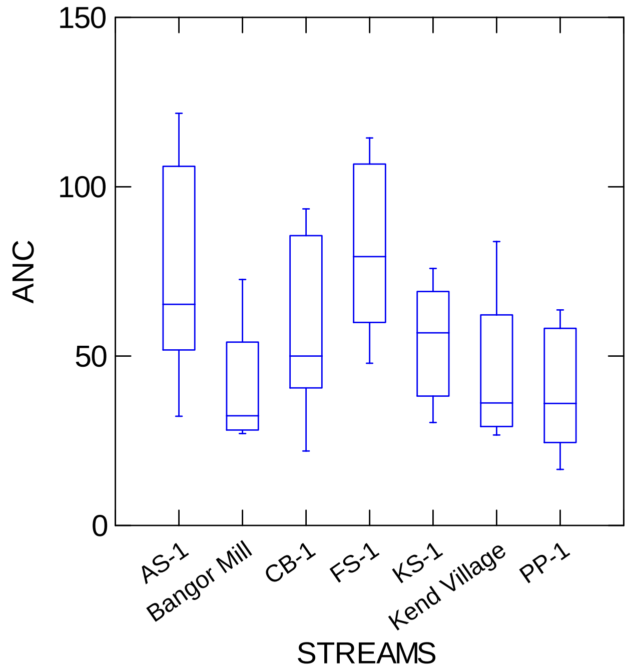
Alkalinity in the Kenduskeag and tributary sites is robust (Table 5) and accounts for the lack of vulnerability to acid rain or other large swings in pH. The PEARL website shows that Garland Pond (with a mean alkalinity of 52 mg/L) is among the highest 4% for any lake in the state for ANC (see PEARL for individual lake data and VLMP website for comparative information). In contrast, the average alkalinity for the Sheepscot River ranges from about 10-18 mg/L with the lower values found in the upper Sheepscot and the higher values found in the lower West Branch (DEP 2005). Sheepscot Pond has an average alkalinity of 8.8 mg/L, and is found in the mode (5-10 mg/L) for Maine Lakes (PEARL and VLMP).

Table 5. Mean alkalinity (ANC) in mg/L for Kenduskeag Stream and upper tributary sites, with standard deviation and ranges.

	ANC mean	No. cases	Std Dev	Range
Crooked Brook	53.9	13	27.6	22-93
Kenduskeag Stream	47.9	12	24.9	31.6-75.9
Allen Stream	68.9	13	34.4	32.2-122.7
French Stream	75.2	13	32.2	47.9-109.3
Pierre Paul Brook	36.4	13	20	16.6-63.7

The high alkalinity of the Kenduskeag watershed is primarily due to the marine sedimentary bedrock that dominates the area. The Waterville Formation in the upper watershed and the Vassalboro Formation in the lower watershed are both marine. However, the Waterville Formation has limestone members, while the Vassalboro Formation formed in shallow water primarily from weathered volcanic deposits. This bedrock pattern is reflected in the relatively higher ANC in the upper sites as opposed to the samples from Kenduskeag Village and Bangor. Agriculture is a secondary source of both carbonate and calcium since lime is added to soils to improve soil fertility.

Figure 3. Box plot of medians and ranges for ANC (in mg/L) for all sites. The Allen Stream, Crooked Brook, French Stream, Kenduskeag Stream, and Pierre Paul Brook sites are abbreviated. Kenduskeag Village and Bangor are below our regular sample sites. Pierre Paul Brook is a boggy stream in a not very agricultural part of the watershed. Pierre Paul Brook is the approximate break-point between the lime rich Waterville Formation and the volcanic rich Vassalboro Formation. Boxes and bars are quartiles above and below the median.



Calcium:

Calcium is the dominant cation in most freshwater systems. Calcium is also an important nutrient for plant and animal life. Calcium plays a role in buffering aquatic life from the toxic effects of aluminum that come from acidic soils. The average total aluminum in all Kenduskeag and tributary samples is 59 ug/L (range less than 10-190 ug/L). The exchangeable aluminum for five samples that were field filtered, field acidified and passed through an exchange column in the field ranged 0-18 ug/L. While this is low, any exchangeable aluminum is a concern for fish health. High concentrations of calcium (especially values above 10 mg/L) mitigate aluminum toxicity. Fishery biologists like to see calcium at least 10 mg/L and even 40 or more for the best nutrition and health (Russell Danner, Maine Dept Inland Fisheries & Wildlife, personal communication). Kenduskeag Steam and its upper tributaries have this ideal range.

Table 6. Mean calcium concentration in mg/L for Kenduskeag Stream and upper tributary sites, with standard deviation and ranges.

	Ca mean	No. cases	Std Dev	Range
Crooked Brook	20.9	14	6.68	9.38-30.2
Kenduskeag Stream	18.82	14	5.26	11.4-25.7
Allen Stream	25.82	14	7.7	13.5-37.3
French Stream	26.04	14	6.25	16.2-33.4

Pierre Paul Brook	12.89	14	4.63	6.39-19.4

Chloride:

After bicarbonate, chloride is often the most important anion in freshwater. It comes primarily from marine aerosols and road salt. The marine sedimentary rocks that dominate the Kenduskeag watershed are a minor source of chloride, since bedrock decomposes very slowly.

Table 7. Mean chloride concentration in mg/L from Kenduskeag, upper tributary sites, and occasional upper (Burnham Brook and spring) and lower watershed sites (Kenduskaeg Village and Bangor), with standard deviation and ranges.

	Cl mean	No. cases	Std Dev	Range
Crooked Brook	7.63	14	2.05	4.5-11.24
Kenduskeag Stream	4.81	14	1.43	3.01-7.73
Allen Stream	6.43	14	2.15	3.58-10.74
French Stream	7.48	14	2	4.79-10.74
Pierre Paul Brook	6.24	14	2.03	3.4-9.71
Burnham Brook	1.2	1		
Garland spring site	33.36	1		
Kenduskeag Village	6.62	4	3.02	4.45-10.95
Bangor Mill	10.73	4	3.85	7.55-15.74

According to the National Atmospheric Deposition Program (NADP) National Trends Network (NADP website), chloride in this part of Maine ranges from 0.15-0.20 mg/L in rainfall. Chloride becomes concentrated in the groundwater by evapotranspiration to as much as 3.5 mg/L (Stephen Norton, U of Maine, personal communication). The Garland spring site is next to a public road and is clearly contaminated. Many of our samples have two to four times the uppermost expected value. The Maine drinking water standard for chloride is 250 mg/L, but people on sodium restricted diets may need to avoid water sources with more than 20 mg/L sodium (DHHS website). This comes out to 31 mg/L of chloride, so drinking from the spring could be hazardous to people that have to restrict their sodium intake. A concentration of 30 mg/L or more of chloride is also known to be harmful to roadside vegetation (Kaushal et al, 2005).

During the winter, approximately 140,000 tons of salt are applied to Maine roads to improve traffic safety (DEP 1998). Application rates vary, but amount to about 13 tons per mile of road for an average winter (Brian Burne, MDOT, personal communication). Highway runoff can be as salty as the ocean (Riverside Stewardship Alliance website). In a study on the effects of road salt that included both rural and urban sites around Baltimore (Kaushal et al, 2005), rural agricultural sites with no road crossings in the watershed had chloride values that ranged from 2-8 mg/L. Except for the spring site our range is 3-11 mg/L. Since Burnham Brook is a headwater stream with only a seasonal camp, predominantly forest with some pasture, and only one dirt road, this sample site is probably a reasonable reference value (1.2 mg/L). Depending on what you take as a reference value, our samples are slightly to moderately enriched with chloride. The sodium to chloride ratio in our samples is 0.914 (rock salt has a sodium to chloride ratio of almost 1.0 while sea salt is about 0.8, Ken Johnson, University of Maine, personal communication). Our ratio shows a mix our sources. The source of chloride enrichment above the marine aerosol background is road salt and the effects are especially pronounced in Bangor and the roadside spring in Garland.

Sulfate:

Sulfate is the next most abundant anion in freshwater after chloride. It comes from marine aerosols, acid rain (wet and dry deposition), and in some cases from agriculture. Bedrock can be a source for sulfate, but is generally secondary to the sources mentioned above. The NADP website gives the concentration of sulfate in rainfall as 0.75-1.00 mg/L for this part of Maine. Additional sulfate comes from dry deposition, especially that intercepted by trees. Sulfate is further concentrated in groundwater to about 3 mg/L (Stephen Norton, personal communication) by evapotranspiration. We have more than that in our samples (Table 8), sometimes more than twice as much. This suggests another source, such as an agricultural or bedrock contribution. According to Dan Schmidt, the District Conservationist for NRCS for the Kenduskeag watershed, ammonium sulfate and/or manure are commonly used by local farmers as fertilizers. Ammonium sulfate could be the source of the enrichment. Sulfate is not known to cause any problems for aquatic life forms at these concentrations.

Table 8. Sulfate mean concentration in mg/L for Kenduskeag, tributary sites, and occasional lower watershed sites, with standard deviation and ranges.

	SO4 mean	No. cases	Std Dev	Range
Crooked Brook	4.76	14	0.84	3.27-6.29
Kenduskeag Stream	4.04	14	0.61	3.07-5.33
Allen Stream	5.73	14	1.44	2.93-7.83
French Stream	5.04	14	1.85	2.55-8.12
Pierre Paul Brook	2.93	14	0.94	1.73-4.66
Kenduskeag Village	4.02	4	0.73	3.07-4.85
Bangor Mill	3.87	4	0.68	2.93-4.51

Nitrate:

Nitrate is not generally abundant in unpolluted surface waters, however biological uptake and recycling are very active in healthy aquatic communities. We find a range of nitrate values from the headwater stream Burnham Brook, to the contaminated spring site (Table 9) and in our regular sampling sites. Nitrate comes from acid rain (wet and dry deposition), from fertilizers, and from septic systems or manure. The extreme value at the spring in Garland is apparently from a nearby up-hill septic system. The Maine drinking water standard is 10 mg/L nitrate (DHHS website). Nitrate binds with hemoglobin in blood and can lead to a fatal condition in infants and young children.

Table 9. Nitrate mean concentration in mg/L for Kenduskeag, upper tributary sites, and occasional sites upstream (Burnham Brook headwater and spring site by Garland Pond) and downstream sites, with standard deviations and ranges.

	NO3 mean	No. cases	Std Dev	Range
Crooked Brook	1.07	14	0.67	0.1-2.29
Kenduskeag Stream	1.16	14	0.55	0.62-2.05
Allen Stream	1.74	14	0.95	0.58-3.84
French Stream	1.12	14	1.02	0.23-3.91
Pierre Paul Brook	0.41	14	0.4	0.07-1.43
Burnham Brook	0.33	1		
Garland spring site	8.37	1		
Kenduskeag Village	0.84	4	0.42	0.27-1.18
Bangor Mill	0.7	4	0.53	0.08-1.36

In the Kenduskeag watershed, nitrate in rainfall averages 0.7 mg/L (NADP). However, unlike sulfate, nitrate is an important plant nutrient and it does not become concentrated in groundwater to the same extent that sulfate does. Because of the different sources of nitrate and the unpredictable amount of biological uptake, NADP values cannot be used to estimate a baseline. Again, the headwater stream Burnham Brook (0.33 mg/L nitrate) probably represents our best estimate of background conditions. Another way to evaluate nutrient enrichment is to look at available regional data. Based on a study of 63 minimally impacted small watersheds in the United States, the glacial upper Midwest and northern New England (Ecoregion VIII, Smith et al, 2003) has an expected background of 0.25 mg/L for total N (including acid rain inputs). An EPA study (2001) also uses data from a number of reference sites and recommends a background value of 0.38 mg/L total N for northern New England. We did not measure total N, but nitrate values are generally about 50% of total N values for Maine streams (Tom Danielson, DEP, personal communication). This suggests the regular sample sites have 2-13 times as much nitrate as expected background conditions. The downstream sites (Kenduskeag Village and Bangor) have lower mean concentrations than the regular sample sites. This also suggests enrichment in the most agricultural section of the river and dilution by downstream tributaries.

Allen Stream has the highest mean nitrate concentration and Pierre Paul Brook has the lowest. We have not finished our GIS mapping project and so do not have land cover totals for each subwatershed. However, Allen Stream is one of the most intensively agricultural while Pierre Paul Brook is the least. Pierre Paul is also the most boggy and has the most water color. Bogs and other saturated soils can be important sinks for nitrate due to anaerobic bacterial activity. According to Peterson et al (2001), small streams (defined here as being less than 10 m in width) are like bogs in that they consume more nitrate than they export. The nitrate is taken up by stream side vegetation and is used by anaerobic microbes in saturated soils. All of our regular tributary sites would be classified as "small streams."

Total Phosphorus:

The other nutrient of interest is phosphorus, here measured as total phosphorus (or total P). Phosphorus in streams comes from soils and road runoff. The five regular sites have about the same amount of total P with similar ranges (Table 10). The highest total P values for a given site come from two days in 2005 that were especially rainy (see section C The Relationship of Water Chemistry with Flow). No phosphorus samples were taken from the headwater stream Burnham Brook. The lower sites (Kenduskeag Village and the Bangor Mill) have very high means due to the predominance of stormwater samples (two of three, or three out of four samples). The actual values are not much different from the upstream sites for a given day. The fact that the highest values are in Bangor probably may be significant due to the urban setting. But the urban enrichment, if any, is small.

Table 10. Total P mean concentration in ug/L for Kenduskeag and tributary samples, with occasional lower river sites, with standard deviation and ranges.

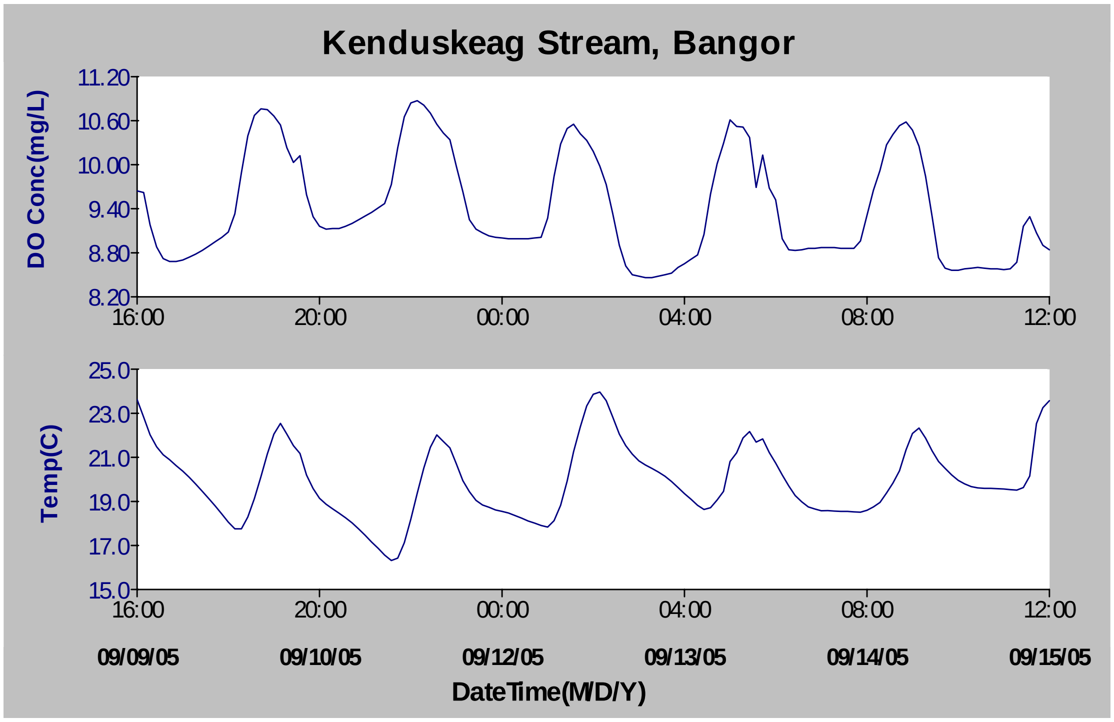
	Total P mean	No. cases	Std Dev	Range
Crooked Brook	26.2	12	35.2	10-102
Kenduskeag Stream	20.7	12	41	6-107
Allen Stream	22.7	12	32.9	8.8-84
French Stream	25.5	12	29.6	9.4-86
Pierre Paul Brook	26.5	12	28.6	8.7-79
Kenduskeag Village	50.3	3	14.1	13-105
Bangor Mill	92.7	4	66.5	16-135

Depending on the reference study, background values for northern New England might range from 10 ug/L (EPA 2001) to 15 ug/L (Smith et al, 2003). On a given day, many of our sample values are between 10 and 20 ug/L (e.g., the mode for the Kenduskeag is 9.6 and the mode for Crooked and Pierre Paul Brooks are 14 ug/L) but the stormwater values are often very high (approaching 100 ug/L or more). Phosphorus enrichment of these streams appears to be primarily due to stormwater runoff.

Dissolved Oxygen:

In two years of field testing, we found that all of our sites had at least 7 ppm oxygen and 70% oxygen saturation even in the summer. A data sonde (a programmable automated environmental recorder) was placed in the river for one week at the upper and lower Kenduskeag sites (Corinth and Bangor respectively). For both deployments, the diurnal oxygen curve stayed above 7 ppm and 70% and the diurnal range was approximately 2.0 ppm (Figure 4). This limited range is indicative of a healthy river.

Figure 4. Dissolved oxygen and water temperature for Kenduskeag Stream near the Bangor Mill site. An automated recorder (data sonde) was set to record environmental hourly.



Transparency:

Water transparency was measured streamside with a 120 cm turbidity tube. The tube has a secchi disk in the bottom and measures the amount of water in the tube where the secchi target finally becomes invisible. Maximum transparency is 120 cm. Transparency declined during and after all storm events and was as little as 15 cm (in Bangor). In general, Crooked Brook had the lowest transparency among the regular sites (Table 11). Among all sites, the Bangor Mill site had the lowest transparency for a given storm sample (except for once when Crooked Brook was worse). In spite of these differences, the means and ranges for the regular sites and occasional sites are very similar (i.e., on a given storm day the entire river was cloudy).

This year we did not take samples for lab analysis of suspended solids and turbidity, preferring to use the turbidity tubes instead. Maine does not have a numerical TSS or turbidity water quality standard. In Minnesota, the state water quality standard is 10 NTU for cold water fisheries and 25 NTU for cool water fisheries.(which in Minnesota waters translates to a transparency tube measurement of about 22 cm) (MPCA 2000). In the salmon rivers, only the worst turbidities from Cove Brook have been 25 NTU or more. Any time visibility is poor (5-100 NTU), this will become a problem for fish if it lasts for many hours to a few days (Newcomb & Jensen, 1996). The Kenduskeag experiences turbidity conditions that are a moderate stress for fish. Naturally, some life stages are more sensitive than others.

Table 11. Water transparency measured in a 120 cm turbidity tube (maximum visibility is 120 cm). Low means from Kenduskeag Village and Bangor are due to the predominance of storm samples taken from these sites.

	Transp Mean	No. cases	Std Dev	Range
Crooked Brook	75.6	9	44.5	21-120
Kenduskeag Stream	81.3	9	42.8	22-120
Allen Stream	80.5	8	46.1	36-120
French Stream	90.5	8	40.1	29-120
Pierre Paul Brook	86.7	8	46.4	29-120
Kenduskeag Village	47.8	6	39.3	22-120
Bangor Mill	48.8	6	41.2	15-120

C. The Relationship of Water Chemistry with Flow:

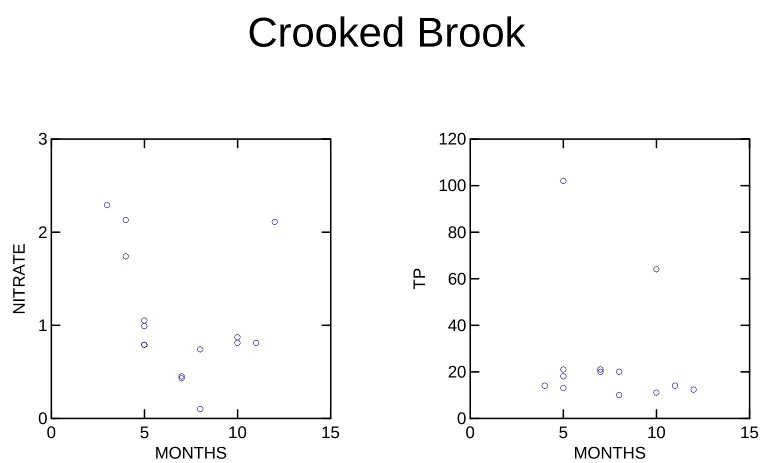
The relationship of nutrients with flow variables was investigated graphically and by regression analysis. The flow variables were river stage measured with a staff gauge, relative flow estimated from the Sebasticook R, and measured discharge. All five tributaries have seasonal maxima in nitrate and total phosphorus concentrations during the spring and fall (Figures 5-9). Nitrate maxima appear to occur earlier, especially March and April and later in the year, in October and December than phosphorus maxima. However R^2 values for nitrate (Table 12) are poor (0.1 or less) except for Crooked Brook and measured discharge. In contrast, R^2 values with total P and at least one flow variable are good (R^2 of 0.5 or better). A log transformation of the data did not improve the results.

Table 12. R^2 values for linear regressions of nitrate or total P with various flow indicators. Discharge was measured in cubic feet per second. Only two sites had more than 3 discharge measurements for a regression analysis (N=5).

Site Name	Stage vs NO3	Stage vs TP	Rel Flow vs NO3	Rel Flow vs TP	Meas. Discharge, cfs vs NO3	Meas. Discharge, cfs vs TP
Crooked Brook	0.0219	0.1695	0.0219	0.5399	0.8542	-0.0962
Kenduskeag Stream	-0.0105	0.6339	0.0105	0.6339	0.0151	0.4146
Allen Stream	0.0009	0.6061	0.0005	0.1813		
French Stream	0.0632	0.6649	0.0632	0.5949		
Pierre Paul Brook	0.1011	0.7533	0.1011	0.7533		

For Crooked Brook, the spring and fall nitrate maxima are a mix of snow melt (N=1), storm flow (N=4), and baseflow samples (N=2). Because one of the baseflow samples nevertheless had a high associated flow, the regression with measured discharge turns out very well (R^2 0.8542). The two phosphorus maxima are associated with the two largest storms in our data set (on 5/25/05 a 2.5 inch storm with a weekly total of 3.35 inches and on 10/9/05 with 8.1 inches of rain over 48 hours). The graphic analysis (Figure 5) suggests that nitrate transport is seasonal rather than flow related, perhaps due to a lack of winter cover crops and/or the dormancy of vegetation during this part of the year. Without plant and microbial uptake, nitrate is more likely to run off. While the snow melt sample and the high spring and fall stormwater values suggest acid rain enrichment, the mix of baseflow samples shows this is not the only explanation. Local groundwater does not appear to be greatly enriched in nitrate, since summer baseflow samples are among the lower values. The relationship of flow with total P is weak except for the largest storms.

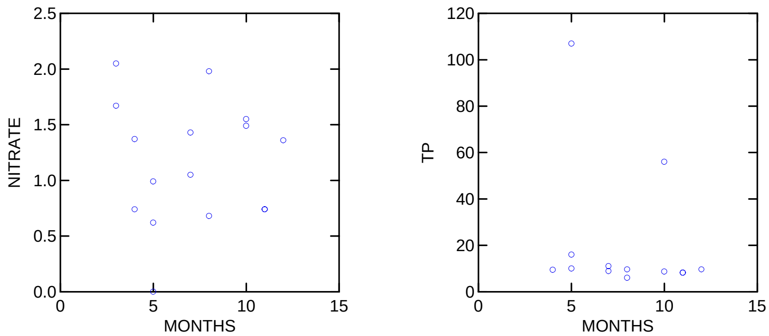
Figure 5. Scatter diagram of nitrate and total P by month for Crooked Brook.



For Kenduskeag Stream there is no apparent seasonal effect, maxima occur any time of year and are associated with snow melt, storms, and baseflow events. The biggest storms have fairly median nitrate values. For phophorus, the same pattern is seen with the highest values associated with the largest two storms in the data set.

Figure 6. Scatter plot of nitrate and total P for Kenduskeag Stream at the Corinth site.

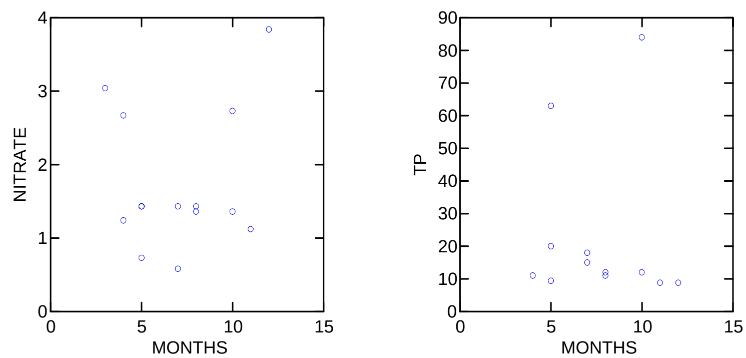
Kenduskeag Stream



In Allen Stream, there is an apparent seasonal pattern, but the pattern is not flow related (the nitrate maxima are a mix of one snow melt, one storm, and two baseflow samples). The total P maxima are associated with the same two largest storms.

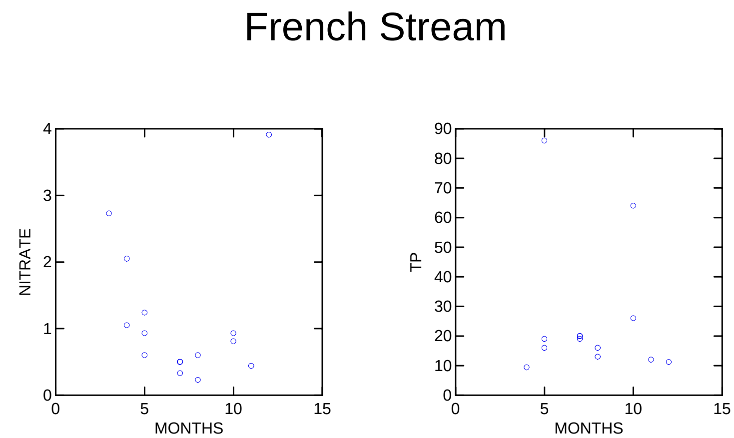
Figure 7. Scatter plot of nitrate and total P in Allen Stream.

Allen Stream



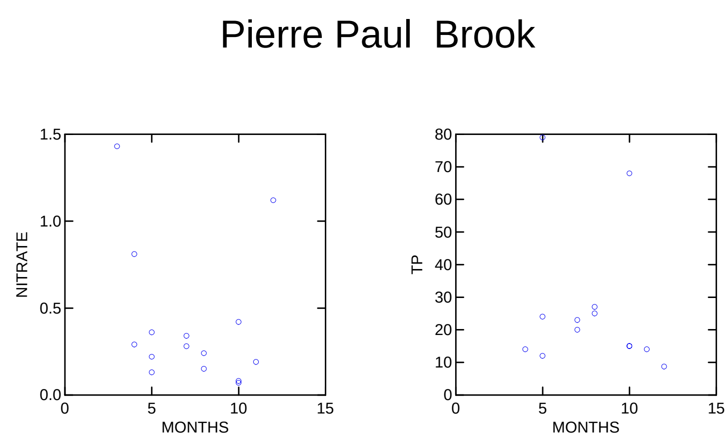
In French Stream there appears to be a seasonal pattern in nitrate, but the maxima correspond to one snow melt, one storm, and one baseflow sample. Total P is associated with the two largest storms.

Figure 8. Scatter plot of nitrate and total P for French Stream.



For Pierre Paul Brook, the nitrate values are lower than the other stream sites and there is a seasonal pattern. The nitrate maxima are one snow melt, one storm and one baseflow sample. The total P maxima are the two large storms.

Figure 9. Scatter plot of nitrate and total P for Pierre Paul Brook.



Summary:

The Kenduskeag and its upper tributaries have unusual chemistry. The high pH and high buffering capacity places these streams among only 4% of Maine’s surface waters. The high buffering capacity is adequate to protect the river from acid rain inputs and the calcium levels are close to ideal for fish nutrition. The high pH, alkalinity and calcium levels are due to bedrock formations that contain limestone (Waterville Formation). The concentration of toxic aluminum (the exchangeable Al) is very low due to the high pH.

Water quality summary for Kenduskeag Stream and upper watershed tributaries
By Mark Whiting, Maine DEP, March 2006

Like the interim report, we conclude that the upper Kenduskeag and upper tributaries are slightly enriched with nutrients, sulfur and road salt. There is also some moderate turbidity associated with high flow events. Samples from the lower river suggest that the nutrient, salt, and turbidity problems become worse within the Bangor city limits. The nutrient enrichment is not causing nuisance algal blooms or oxygen depletion. Nitrate is exported from the watershed primarily in the early spring and late fall when there is minimal plant uptake. Phosphorus is exported primarily during the largest storm events, but otherwise the relationship with flow is weak. These largest storms also correspond with the periods of highest and longest lasting turbidity. Data sonde deployments in the upper and lower river suggest a healthy balance of biological activity. Oxygen sags like those in the Sheepscot have not been observed.

The Kenduskeag watershed is one of the most intensively agricultural areas in Penobscot County. Large dairy farms, other livestock, potato and market gardens, and a few orchards dominate the agricultural landscape. A report by the Penobscot County Soil and Water Conservation District identified erosion and sedimentation, low oxygen saturation (as low as 10% in the lower river), high coliform bacteria, excessive nutrients and fish habitat degradation as the chief problems (PC SWCD 1988). Our study concentrated on the upper watershed which is the most agricultural part. We have only begun to look at the lower river. However, our study suggests that there has been considerable progress with improved agricultural practices. Except for some high E coli counts, the river meets state Water Quality Criteria for a Class A river. The river supports Atlantic salmon, a small brook trout fishery, and a rich assemblage of invertebrates. The river is known locally for its canoe and kayak recreation and is fondly thought of by its human communities.

Currently the greatest needs are for better information about the lower river, greater reductions in bacteria in the upper and lower river, and perhaps even better nutrient management on farms and residential parcels.

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